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TRANSMITTAL

TO: Jennifer Fitch, PE Project Manager Vermont Agency of Transportation	DATE	PROJECT NO.
	4/18/2014	Brookfield BRF FLBR (2)

XX WE ENCLOSE THE FOLLOWING: ______ UNDER SEPARATE COVER WE ARE SENDING THE FOLLOWING

COPIES	NUMBER	DESCRIPTION	CODE
1		FRP Design Computations - Rev 0	H
1		FRP Design Drawings - Rev 0	H
1		Planned Deviations from Conceptual Design - Rev 0	H
1		Historical Laminate Test Data	H

CODE:

A FOR INITIAL APPROVAL
B FOR FINAL APPROVAL
C APPROVED AS NOTED-RESUBMISSION REQUIRED
D APPROVED AS NOTED-RESUBMISSION NOT REQUIRED
E DISAPPROVED-RESUBMIT
F QUOTATION REQUESTED
G APPROVED
H FOR APPROVAL
I AS REQUESTED OR REQUIRED
J FOR USE IN ERECTION
K LETTER FOLLOWS
L FOR FIELD CHECK
M FOR YOUR USE

Historical laminate test data included for justification of estimated laminate properties in design computations.

BY: Paul [signature]

FRP Raft Pontoons – Supporting Comps

For

Brookfield Floating Bridge

In

Brookfield, Vermont

CEE 050-br-14 Vtrans BLF – FLBR(2)

Prepared for:

Miller Construction, Inc

By:

Kenway Corporation

April 18th, 2014

Predicted Material Properties for Pontoon Laminate

Fabric	Architecture	Areal Wt. (oz/yd^2)	E_x (=E_y) (Msi)	F_{tu} (ksi)	F_{cu} (ksi)	G (Msi)	F_{su} (ksi)
Biaxial	0/90 no mat	54	3.76	60.2	60.2	0.52	10.4
Bias	±45 w/mat	48	1.59	15.9	15.9	1.64	31.0
Laminate	$[0/90]_7[\pm45]_2$	528	3.48	54.7	54.7	0.69	13.9

*Laminate properties are determined using "VectorLam" software by VectorPly. Compression properites are increased to match predicted tensile based on previous test data by Umaine (see attached test report).

Ply	Description	Roll Dir.	Ply Thk (in)	Total Thk (in)
10	4008 double bias	0	0.058	**0.533**
9	5400 biaxial	0	0.058	0.475
8	5400 biaxial	0	0.058	0.417
7	5400 biaxial	0	0.058	0.359
6	5400 biaxial	0	0.058	0.301
5	5400 biaxial	0	0.058	0.243
4	5400 biaxial	0	0.058	0.185
3	5400 biaxial	0	0.058	0.127
2	4008 double bias	0	0.058	0.069
1	C-veil (against mold)	0	0.011	0.011

Laminate Compostion

Item	Description	Manufacturer	W_f (fiber)	Remarks
Resin	8100-50 vinyl ester	Interplastics	n/a	w/UV inhibitor and gray pigment
Fabric	54 oz 0/90 3D woven	TEAM	72%	
Fabric	48 oz ±45 stitched	FGI	71%	40 oz fabric plus 8 oz/yd^2 csm
Fabric	C-veil (glass)	PPG	65%	surfacing veil against mold
			71.5%	*laminate fiber fraction by wt.*

Infusion Process

A detailed diagram of the infusion process indicating placement of vacuum lines, release film, flow media, feed lines, etc. will be provided for each component as part of the fabrication drawings submittal. A general summary of the process to be utilized is described below.

All parts will be laid up in vacuum tight molds. A perimeter vac line broken up into multiple zones will be used to evacuate air from the part. The normal operating range of our vac system is 25–29" Hg. A layer of release film is placed over the entire part prior to placing the shade cloth, which acts as a flow medium for the resin between feed lines. Feed lines will be placed across the part every 16–18" starting at the center. After a drop test has been successfully performed, the center feed will be opened. Once the flow front is 3–6" past the adjacent feed line, the next feed line is opened until the part is full of resin. Vacuum lines are kept open until the part has gel'd and feed lines are kept open until the resin has gel'd in the bucket. A gel time of approximately 40–50 minutes is the target. Resin will be dispensed from a Magnum Venus Products (MVP) system, which mixes resin and catalyst at the desired ratio at the gun nozzle as it is dispensed.

Estimated Pontoon Weight

ITEM	DESCRIPTION	MAT'L	L (ft)	W (ft)	T (in)	Area (ft^2)	Vol. (ft^3)	Density lb/ft^3	WEIGHT (lb/item)	Qty. (ea.)	WEIGHT (lb)
1	Top Plate	FRP	51.0	11.5	0.50	587	24.4	121.0	2957	1	2,957
2	Hull (bot. & sides)	FRP	51.0	16.1	0.50	861	35.9	121.0	4343	1	4,343
3	Trans. Blkhd - Mid	FRP	11.0	3.00	0.50	38.9	1.6	121.0	196	3	589
4	Long. Bkhd - Mid	FRP	12.5	3.00	0.50	45.3	1.9	121.0	228	2	456
5	Long. Bkhd - End	FRP	13.0	3.00	0.50	46.3	1.9	121.0	233	2	466
6	Trans. Blkhd - End	FRP	5.50	3.00	0.50	20.8	0.9	121.0	105	4	418
7	Thickened areas	FRP	102	0.50	0.50	51.0	2.1	121.0	257	1	257
8	Rigid Closed Cell Foam	PU	50.0	11.0	36.0	32.1	1,540	2.0	3081	1	3,081
9	Pultruded Tube, 2"x1/4"	FRP	2.00	2.00	0.25	0.01	0.1	112.7	15	3	45
10	PT Blister, 7"x7"	FRP	0.58	0.58	0.75	0.34	0.02	121.0	3	3	8
11	Adhesive	MMA	151	0.25	0.13	38	0.39	59.5	23	1	23
										Total	**12,644**

Raft Wt. (lb) = **25,287**

22,000 < **25,287** < 33,000

Measurements are based on sectioned SolidWorks model
Section Properties of the selected faces of Pontoon Assembly - Copy

Area = 662.55 inches^2

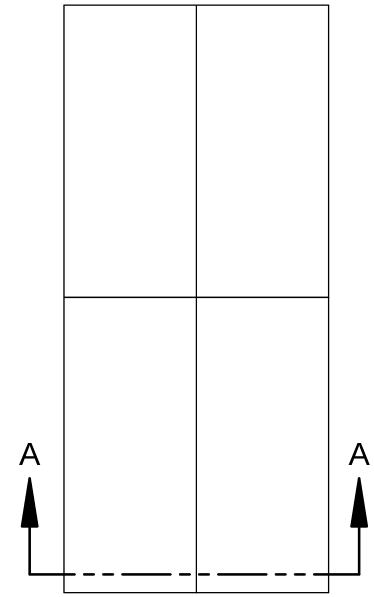
Centroid relative to assembly origin: (inches)
X = -0.00
Y = 19.02 (16 < Y , 20)
Z = 15.68

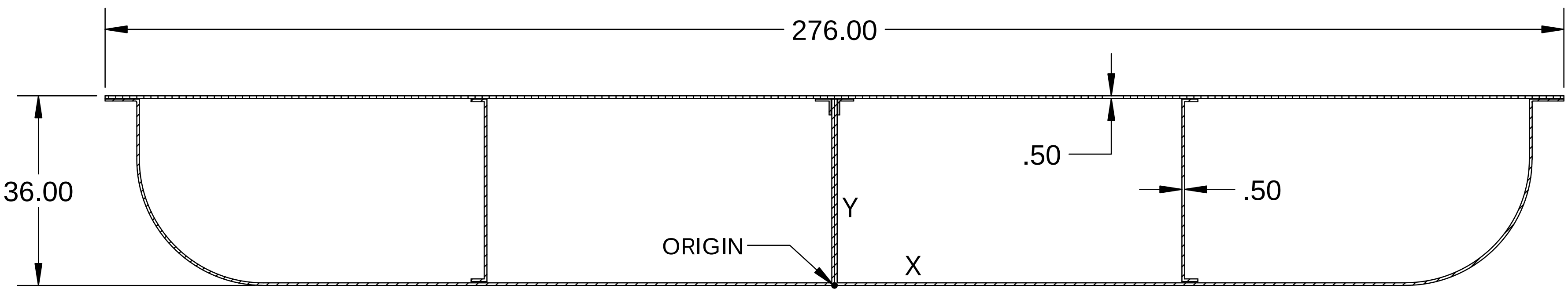
Moments of inertia of the area, at the centroid: (inches ^ 4)

Lxx = 171207.78	Lxy = 0.00	Lxz = 0.00
Lyx = 0.00	Lyy = 4228433.92	Lyz = 0.00
Lzx = 0.00	Lzy = 0.00	Lzz = 4399641.70

Predicted E of laminate = 3,480 ksi x 0.95 (Cm) = 3,420

Raft vertical bending stiffness = 595,804,000 kip-in^2 > 260,000,000





SECTION A-A

		UNLESS OTHERWISE SPECIFIED:		NAME	DATE
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL± ANGULAR: MACH± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN		
			CHECKED		
			ENG APPR.		
			MFG APPR.		
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
		MATERIAL	COMMENTS:		
NEXT ASSY	USED ON	FINISH			
APPLICATION		DO NOT SCALE DRAWING			

PROPRIETARY AND CONFIDENTIAL

THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <INSERT COMPANY NAME HERE>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <INSERT COMPANY NAME HERE> IS PROHIBITED.

TITLE:

RAFT SECTION PROPERTIES

SIZE	DWG. NO.	REV
A		

SCALE: 1:192 WEIGHT: SHEET 1 OF 1

5 4 3 2 1

<u>Bottom Plate</u>

Maximum vertical bending moment on raft - Strength V (bottom in compression)

$$\boxed{M_u \le C_m \lambda \phi M_n}$$

Bottom plate stabilized by water pressure and sprayed-in-place flotation foam - buckling not evaluated.

Rupture (evaluated as a composite section)

$$\boxed{M_n = \frac{F_L I}{y}}$$

F_L =	54.7	ksi		λ =	0.90		
I =	48,086	in^4		ϕ =	0.65		
y =	19.3	in		C_m =	0.85		
$C_m\lambda\phi M_n$ =	5,644	kip-ft	>	M_u =	1,612	kip-ft	(Sheet 37)

Rupture (evaluated as a plate in compression)

$$\boxed{N_u^c \le C_m \lambda \phi_c N_n^c} \qquad \boxed{N_n^c = F^c t}$$

				M_u =	1,612	kip-ft	(Sheet 37)
F^c =	54.7	ksi		d =	36	in	(section depth)
t =	0.53	in		C =	537	kip	(compressive force)
λ =	0.90			b =	18	ft	(width of bot. plate)
ϕ =	0.70						
C_m =	0.85						
$C_m\lambda\phi_c N_n$ =	15.5	kip/in	>	N_u =	2.49	kip/in	

$$\boxed{N_u^c = \frac{C}{b}}$$

Top *Plate Buckling (evaluated as a plate in compression - Strength III)*

$$\boxed{N_u^c \le C_m \lambda \phi_c N_n^c} \qquad \boxed{N_n^c = F^{cr} t} \qquad \boxed{F^{cr} = \left(\frac{t}{b}\right)^2 \frac{\pi^2}{6}\left((4k_{cr} - 3)\sqrt{E_L E_T} + k_{cr} E_T \nu_{LT} + 2k_{cr} G_{LT}\right)}$$

M_u =	1,056	kip-ft	(Sheet 37)	d =	36	in	(section depth)
w =	23	ft	(top plate)	C =	352	kip	(compressive force)
F^{cr} =	4.16	ksi		$E_L = E_T$ =	3.48	Msi	
t =	0.53	in		G_{LT} =	0.69	Msi	
λ =	0.90			ν_{LT} =	0.17		
ϕ =	0.70			b =	2.58	ft	(unsupported width)
C_m =	0.95			k_{cr} =	1.2		(1.0 (free) –1.3 (fixed))
$C_m\lambda\phi_c N_n$ =	1.32	kip/in	>	N_u =	1.28	kip/in	

$$\boxed{N_u^c = \frac{C}{w}}$$

Top Plate

Maximum vertical bending moment on raft - Strength V (top in tension)

$$\boxed{M_u \leq C_m \lambda \phi M_n}$$

Rupture (evaluated as a composite section)

$$\boxed{M_n = \frac{F_L I}{y}}$$

F_L =	54.7	ksi		λ =	0.90		
I =	48,086	in^4		ϕ =	0.65		
y =	16.7	in	(36-19.31)	C_m =	0.85		
$C_m\lambda\phi M_n$ =	6,530	kip-ft	>	M_u =	1,612	kip-ft	(Sheet 37)

Rupture (evaluated as a plate in tension)

$$\boxed{N_u^t \leq C_m \lambda \phi_t N_n^t}$$

$$\boxed{N_n^t = 0.7 F^t t}$$

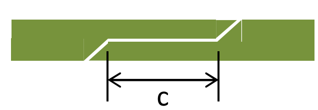
				M_u =	1,612	kip-ft	(Sheet 37)
F^t =	54.7	ksi		d =	36	in	(section depth)
t =	0.53	in		T =	537	kip	(tensile force)
λ =	0.90			b =	22	ft	(width of top plate)
ϕ_t =	0.65						
C_m =	0.85						

$$\boxed{N_u^t = \frac{T}{b}}$$

$C_m\lambda\phi_t N_n$ =	10.1	kip/in	>	N_u =	2.04	kip/in

Top plate seam at midspan - maximum moment at 0.5L on Raft 2

$$\boxed{N_{LT,u} \leq C_m \lambda \phi_v N_{LT,n}}$$



$$\boxed{N_{LT,n} = F^v c}$$

F^v =	2.5	ksi	(MA560 TDS)	M_u =	1,377	kip-ft	(Sheet 37)
c =	3.0	in		d =	36	in	(section depth)
λ =	0.90			T =	459	kip	(tensile force)
ϕ_v =	0.70			b =	22	ft	(width of top plate)
C_m =	0.85						

$$\boxed{N_u^t = \frac{T}{b}}$$

$C_m\lambda\phi_c N_n$ =	4.02	kip/in	>	N_u =	1.74	kip/in

Longitudinal Bulkhead

Maximum vertical shear on raft - Strength V

$$\boxed{V_u \le C_m \lambda \phi V_n}$$

				V_u =	80.8	kip	(Sheet 37)

Rupture (evaluated as a composite section)

$$\boxed{V_n = F_{LT} A_S}$$

				# webs =	4		
				λ =	0.90		
F_{LT} =	13.9	ksi		ϕ =	0.65		
A_S =	17.5	in^2	(35 x 0.5)	C_m =	0.85		
$C_m\lambda\phi V_n$ =	121	kip	>	V_u =	20.2	kip	(V_u / 4)

Rupture (evaluated as a plate in shear)

$$\boxed{N_{LT,u} \le C_m \lambda \phi_v N_{LT,n}}$$

$$\boxed{N_{LT,n} = F_{LT} t}$$

				V_u =	80.8	kip/in	(Sheet 37)
				# webs =	4		
F_{LT} =	13.9	ksi		λ =	0.90		
t =	0.53	in		ϕ =	0.70		
h =	35.0	in	(36 - 2(0.5))	C_m =	0.85		
$C_m\lambda\phi_v N_{LT,n}$ =	3.9	kip/in	>	$N_{LT,u}$ =	0.6	kip/in	(V_u / 4/35.0)

Web Buckling (evaluated as a composite section)

$$\boxed{V_n = f_{cr} A_S} \qquad \boxed{f_{cr} = \frac{t_w^2 k_{LT} \sqrt[4]{E_L E_t^3}}{3h^2}} \qquad \boxed{k_{LT} = 8.1 + 5.0\frac{2G_{LT} + E_t \nu_{LT}}{\sqrt{E_L E_T}}}$$

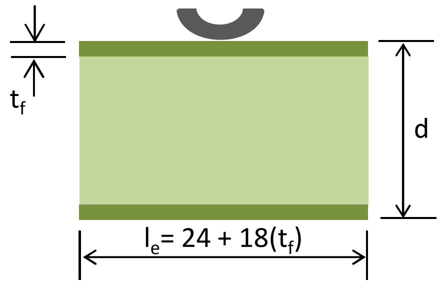
f_{cr}	2.91	ksi		V_u =	80.8	kip/in	(Sheet 37)
A_S =	18.6	in^2	(35 x 0.5)	# webs =	4		
k_{LT} =	10.9		(1.0–1.3)				
t_w =	0.53	in		$E_L = E_T$ =	3.48	Msi	
λ =	0.90			G_{LT} =	0.69	Msi	
ϕ =	0.80			h =	35.0	in	(36 - 2(0.5))
C_m =	0.90			ν_{LT} =	0.17		
$C_m\lambda\phi V_n$ =	35.0	kip	>	V_u =	20.2	kip	(V_u / 4)

Buckling of longitudinal bulkhead due to tire loading

$$\boxed{N_u^c \le C_m \lambda \phi_c N_n^c}$$

$$\boxed{N_n^c = F^{cr} t}$$

$$\boxed{F^{cr} = \left(\frac{t}{b}\right)^2 \frac{\pi^2}{6}\left((4k_{cr} - 3)\sqrt{E_L E_T} + k_{cr} E_T \nu_{LT} + 2k_{cr} G_{LT}\right)}$$



$$\boxed{N_u = \frac{W_u}{l_e}}$$

F^{cr} =	3.26	ksi	
t =	0.53	in	
E_L = E_T =	3.48	Msi	
G_{LT} =	0.69	Msi	
ν_{LT} =	0.17		
λ =	0.90		
ϕ =	0.70		
C_m =	0.95		
k_{cr} =	1.2	(1.0 (free)→1.3 (fixed))	
$C_m\lambda\phi_c N_n$ =	1.03	kip/in	>

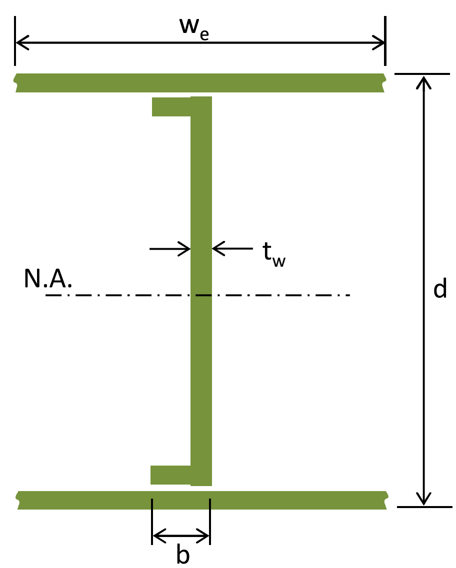
d =	35	in	(unsupported width)
W_u =	15.5	kip	
l_e =	33.5		
N_u =	0.46	kip/in	

<u>Adhesive Bond Strength</u>

Shear transfer from longitudinal bulkhead to top/bottom plate - Strength V

$$\boxed{V \le C_m \lambda \phi F_{LT}}$$

$$\boxed{V = \frac{V_u Q}{Ib}}$$



V_u =	80.8	kip	(Sheet 37)
# webs =	4		
V_u =	20.2	kip	(V_u / 4)
Q =	198	in^3	
w_e =	10.6	in	(20*t_w)
d =	36.0	in	
t_f = t_w =	0.53	kip/in	(V_u / 4)
b =	3.0	in	
I =	6193	in^4	
F_{LT} =	2.50	ksi	(MA560 TDS)
ϕ =	0.65	C_m =	0.85
$C_m\lambda\phi F_{LT}$ =	1.24	ksi	>

λ =	0.90		
V =	0.22	ksi	(V_u / 4)

Bolted Connections - Top/Bottom Flanges

$$\boxed{R_u = \lambda \phi R_n C_\Delta C_M C_T}$$

Pin bearing

$$\boxed{R_{br} = t d_n F_L^{br}}$$

t =	1.06	in	(plate thk)				
d_n =	0.94	in	(dia. +1/16)				
F_{br} =	35.0	ksi	(brng stren.)				
λ =	0.90			C_m =	0.85		
ϕ =	0.80			$C_\Delta = C_T$ =	1.0		
$C_m\lambda\phi R_n$ =	21.4	kip	>	R_u =	19.40	kip	(Sheet 38)

Net tension

$$\boxed{R_{nt} = \frac{1}{K_{nt,L}}(w - n d_n) t F_L^t} \qquad \boxed{K_{nt,L} = C_L\left(S_{pr} - 1.5\frac{(S_{pr}-1)}{(S_{pr}+1)}\Theta\right) + 1}$$

t =	1.06	in	(plate thk)	n =	3	
d_n =	0.94	in	(dia. +1/16)	w =	11.5	(4 x 1.5d+(n-1)g)
F_L =	54.7	ksi	(ten. stren.)	g =	3.5	
C_L =	0.40			$K_{nt,L}$ =	2.48	
λ =	0.90			S_{pr} =	4.67	(g/d)
ϕ =	0.50			Θ =	1.0	($e_1/g \geq 1$)
C_m =	0.85			$C_\Delta = C_T$ =	1.0	

$C_m\lambda\phi R_n$ =	78.0	kip	>	R_u =	19.40	kip	(Sheet 38)

Shear-out

$$\boxed{R_{sh} = 1.4\left(e_1 - \frac{d_n}{2}\right) t F_{sh}}$$

t =	1.06	in	(plate thk)			
d_n =	0.94	in	(dia. +1/16)			
F_{sh} =	13.9	ksi	(shear str.)	e_1 =	3.75	in
λ =	0.90			C_m =	0.85	
ϕ =	0.50			$C_\Delta = C_T$ =	1.0	

$C_m\lambda\phi R_n$ =	67.9	kip	>	R_u =	19.40	kip	(Sheet 38)

Cleavage

$$\boxed{R_{cl} = 0.15\left(\left(e_2 + 0.5g - d_n\right)F_{t,L} + 2e_1 F_{sh}\right)t}$$

$t =$	1.06	in	(plate thk)			
$d_n =$	0.94	in	(dia. +1/16)	$g =$	3.50	in
$F_{sh} =$	13.9	ksi	(shear str.)	$\lambda =$	0.90	
$F_{t,L} =$	54.7	ksi	(tensile str.)	$\phi =$	0.50	
$e_1 =$	3.75	in		$C_m =$	0.85	
$e_2 =$	2.25	in	($2e_{2,min}$)*	$C_\Delta = C_T =$	1.0	

$C_m\lambda\phi R_n =$	43.2	kip	>	$R_u =$	19.40	kip	(Sheet 38)

* since the edge distance in all joints is >> $e_{2,min}$, a value of 2 x $e_{2,min}$ has been used for e_2

Bolted Connections - Vertical Webs

Since the force per bolt acting on the webs is 12.3 kips (less than 19.4 kips evaluated for the flanges), the gage length and end distance is the same as above, and the material properties ($F_{t,L}$, $F_{t,T}$, F_{sh}, etc.) are the same, the bolted connections in the web are assumed to be satisfactory based on calculations performed above for the flanges. However, bearing strength (by far the controlling failure mode) is reevaluated below

$$\boxed{R_u = \lambda\phi R_n C_\Delta C_M C_T}$$

Pin bearing

$$\boxed{R_{br} = t d_n F_L^{br}}$$

$t =$	0.65	in	(plate thk)		
$d_n =$	0.94	in	(dia. +1/16)		
$F_{br} =$	35.0	ksi	(brng stren.)		
$\lambda =$	0.90			$C_m =$	0.85
$\phi =$	0.80			$C_\Delta = C_T =$	1.0

$C_m\lambda\phi R_n =$	13.1	kip	>	$R_u =$	12.30	kip	(Sheet 38)

(1) veil + (4) 4008 + (7) 5400 = 0.648 in.

Compression Loading due to Threaded Rods

Compressive strength of FRP blister

$$\boxed{P_u \le C_M \lambda \phi_c F_c A_e}$$

Axial force, P =	55	ksi	(Sheet 34)	λ =	0.90
Steel brng area, A_s =	36	in^2	(6x6)	ϕ =	0.70
Comp. strength, F_c =	54.7	ksi		C_m =	0.85

$C_m\lambda\phi_c P_n$ =	1055	kip	>	P_u =	77.0	kip	(1.4 x 55)

Compression strength of bulkhead

$$\boxed{P_u \le C_M \lambda \phi_c F_c A_e}$$

Axial force, P =	55	kip	(Sheet 34)	λ =	0.90
Blkhd xsec area, A_s =	18.6	in^2	(35 x 0.53)	ϕ =	0.70
Comp. strength, F_c =	54.7	ksi		C_m =	0.85

$C_m\lambda\phi_c P_n$ =	543	kip	>	P_u =	77.0	kip	(1.4 x 55)

Buckling of transverse bulkhead

$$\boxed{N_u^c \le C_m \lambda \phi_c N_n^c}$$

$$\boxed{N_n^c = F^{cr} t}$$

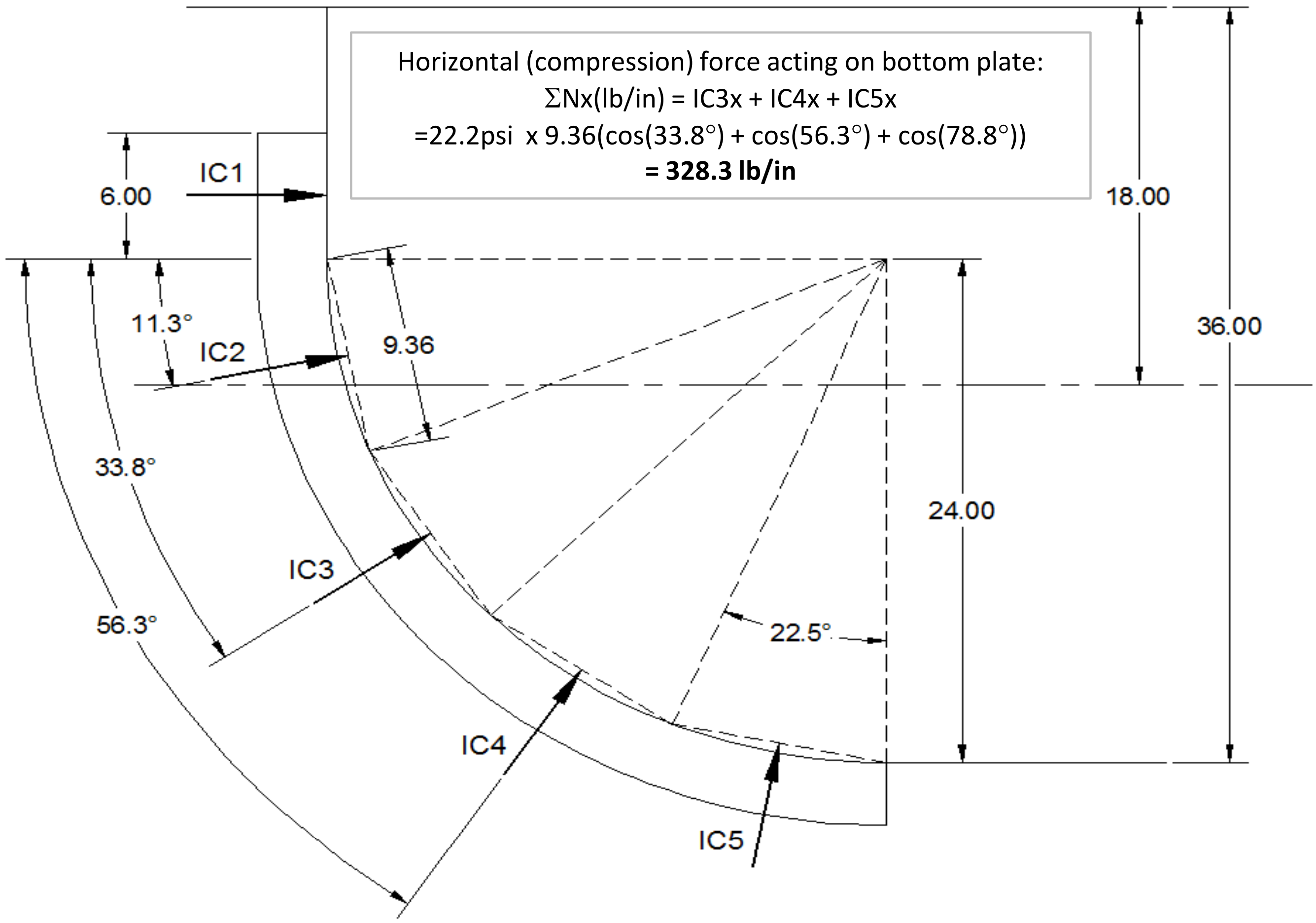
$$\boxed{F^{cr} = \left(\frac{t}{b}\right)^2 \frac{\pi^2}{6}\left((4k_{cr}-3)\sqrt{E_L E_T} + k_{cr} E_T \nu_{LT} + 2k_{cr} G_{LT}\right)}$$

F^{cr} =	3.26	ksi	$E_L = E_T$ =	3.48	Msi	
t =	0.53	in	G_{LT} =	0.69	Msi	
λ =	0.90		ν_{LT} =	0.17		
ϕ =	0.70		b =	35	in	(unsupported width)
C_m =	0.95		k_{cr} =	1.2		(1.0 (free)→1.3 (fixed))

$C_m\lambda\phi_c N_n$ =	1.03	kip/in	>	N_u =	2.20	kip/in	(1.4 x 55 / 35)

*This assumes the bulkhead is not supported between edges. However, the foam provides uniform, continuous bracing on both sides of the bulkhead. Therefore, the unsupported length of the plate, "b", is considered to be 0 and the bulkhead is not at risk of buckling.

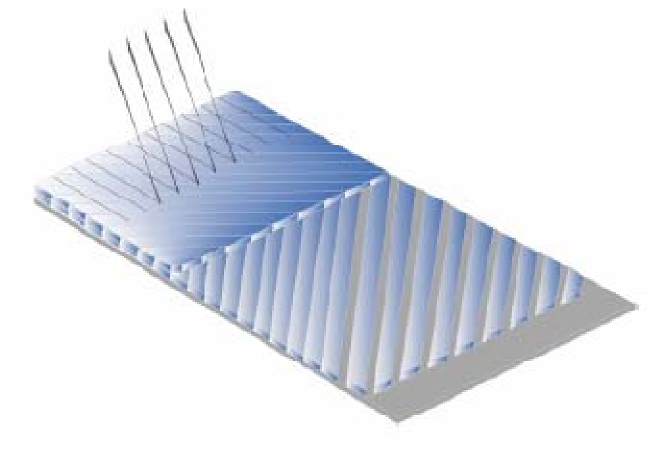
Ice loading



Combined compression (bottom plate - Extreme II + Ice)

M_u =	952	kip-ft	(Sheet 37)	w =	18	ft	(width of bot. plate)
d =	36	in	(sect. depth)	N_T =	0.328	kip/in	(from above)
C =	317	kip	(comp. force)	N_L =	1.469	kip/in	(=C/w)
$C_m\lambda\phi_t N_n$ =	10.1	kip/in	>	N_T =	0.33	kip/in	
$C_m\lambda\phi_c N_n$ =	15.5	kip/in	>	N_L =	1.47	kip/in	

VECTORPLY
Performance Composite Reinforcements



E-BXM 4008

Fiber Type:	E-Glass
Architecture:	45/-45 Double Bias
Dry Thickness:	0.060 in. / 1.52 mm
Total Weight:	48.24 oz/sq.yd / 1636 g/sq.m

Roll Specifications

Roll Width:	Roll Weight:	Roll Length:
50 in / 1270 mm	231 lb / 105 kg	54 yd / 49 m

Fiber Architecture Data

0 ° :	n/a
45 ° :	20.07 oz/sq.yd / 680 g/sq.m
90 ° :	n/a
-45 ° :	20.07 oz/sq.yd / 680 g/sq.m
Chopped Mat :	8.10 oz/sq.yd / 275 g/sq.m

1: Packaging: box or bag.
2: Weights do not include polyester stitching.

Laminated Properties

	45 °	45 °
Laminate Weight		
(lb/sq.ft)	E-BXM 4008 Resin Infused	E-BXM 4008 Open Mold
Fiber	0.34	0.34
Resin	0.15	0.34
Total	0.49	0.67

Physical Properties	E-BXM 4008 Resin Infused	E-BXM 4008 Open Mold
Density (g/cc))	1.88	1.63
Fiber Content (% by Wt.)	69%	50%
Thickness (in)	0.050	0.079

Laminate Modulii		
(MSI)	E-BXM 4008 Resin Infused	E-BXM 4008 Open Mold
Ex	3.51	2.35
Ey	3.51	2.35
Gxy	0.66	0.45
Ex,flex.	3.33	2.23
Ey,flex.	3.33	2.23

Ultimate Stress		
(KSI)	E-BXM 4008 Resin Infused	E-BXM 4008 Open Mold
Long. Ten.	58	39
Long. Comp.	80	54
Trans. Ten.	58	39
Trans. Comp.	80	54
In-Plane Shear	15	10
Long. Flex.	82	55
Trans. Flex.	82	55

In-Plane Stiffness, "EA"		
10^3 lb/in	E-BXM 4008 Resin Infused	E-BXM 4008 Open Mold
(EA)x	175	187
(EA)y	175	187
(GA)xy	33	36

Ultimate In-Plane Load		
lb/in	E-BXM 4008 Resin Infused	E-BXM 4008 Open Mold
Long. Ten.	2,864	3,060
Long. Comp.	3,981	4,254
Trans. Ten.	2,864	3,060
Trans. Comp.	3,981	4,254
In-Plane Shear	753	823

Notes:

1: Resin infused laminate made with a poly / vinyl ester resin blend.

2: Open mold laminate made with poly / vinyl ester resin blend.

3: All standard reinforcements should be infused with a flow aid or Vectorfusion® reinforcements.

VECTORPLY CORPORATION

3500 Lakewood Dr. Phenix City, AL 36867 tel. 334 291 7704 fax. 334 291 7743

REV: 5/3/2011

team
Textile Engineering & Manufacturing

841 Park East Drive
P.O. Box 25
Woonsocket, RI 02895
Phone: 401-762-1500
Fax: 401-762-1580

Product Data Sheet

Product ID:	3D E-glass – 54oz - Ortho
Description:	54 oz Orthogonal Weave E-glass fabric
Raw Material:	PPG Hybon 2022 E-glass or equivalent
Weave:	3D with 2 warp layers, 3 fill layers and Z-binder yarns
Fiber Distribution:	48% warp / 48% fill / 4% Z-yarn
Weight:	54 oz/yd^2 ± 1.5 (1830 gsm ± 50 gsm)
Std. Width:	50” or 60” (± 0.5”)
Edge Type:	Aramid Leno @ Selvedge
Std. Roll Size:	25, 50 or 100 yards

PLEXUS®

A brand of ITW Polymers Adhesives North America

TECHNICAL DATA SHEET

MA560-1

Children & Schools GREENGUARD® Indoor Air Quality Certified

Description

Plexus® MA560-1 is a two-part methacrylate adhesive designed for structural bonding of thermoplastic, metal, and composite assemblies[1]. Combined at a 1:1 ratio, MA560-1 has a working time of 55 to 70 minutes at room temperature and at 74°F (23°C). MA560-1 reaches lap shear values of approximately 500 and 1000 PSI in 3 and 4 hours respectively at a 0.03 in. (0.75mm). This product has been designed for use on large structures where a very long open time product is needed. Plexus MA560-1 is commonly used for bonding stringers and liners into large fiberglass boats with bond lines up to 1.00 in. (25mm) thick. In addition, this product provides a unique combination of excellent fatigue endurance, outstanding impact resistance, and superior toughness. Plexus MA560-1 is gray when mixed and is available in ready-to-use 400 ml cartridges, 5 gallon (20 liter) pails and 50 gallon (200 liter) drums to be dispensed as a non-sagging gel using standard meter-mix equipment[9]. For optimal mixing and flow, stock # 30095 (13-18) mix nozzles are recommended for cartridge dispensing.

Characteristics

Room Temperature Cure		
	▪ Working Time[2]	55 – 70 minutes
	▪ Fixture Time[3]	220 – 240 minutes
	▪ Operating Temperature[6]	-40°F to 180°F (-40°C to 82°C)
	▪ Gap Filling	0.03 in. to 1.00 in. (0.75 mm to 25 mm)
	▪ Mixed Density	7.95 lbs/gal (0.95 g/cc)
	▪ Flash Point	51°F (11°C)

Chemical Resistance[4]

Excellent resistance to:	Susceptible to:
▪ Hydrocarbons	▪ Polar Solvents
▪ Acids and Bases (pH 3-10)	▪ Strong Acids and Bases
▪ Salt Solutions	

Typical Physical Properties (uncured) – Room Temperature

	Adhesive	Activator
Viscosity, cP	145,000-185,000	170,000-205,000
Color	White	Black
Density, lbs/gal (g/cc)	7.74 (0.93)	7.89 (0.95)
Mix Ratio by Volume	1.0	1.0
Mix Ratio by Weight	1.0	1.0

Typical Mechanical Properties (Cured) – Room Temperature

Tensile (ASTM D638)	
▪ Strength, psi (MPa)	2,500 – 3,000 (17.2 – 20.7)
▪ Modulus, psi (MPa)	25,000 – 50,000 (172 – 345)
▪ Strain to Failure (%)	>130
Lap Shear (ASTM D1002)	
▪ Cohesive Strength, psi (MPa)	1,600 – 2,200 (11.0 – 15.2)

Recommended for:

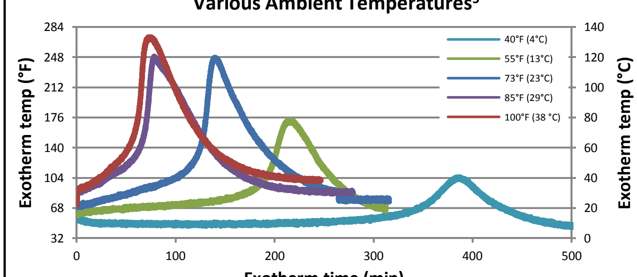
- ABS
- Acrylics
- FRP
- Gelcoats
- PVC
- Polyesters (including DCPD modified)
- Stainless Steel*
- Aluminum*
- Styrenics
- Urethanes (general)
- Vinyl Esters

* **Plexus Primer** Suggested[7]

VOC's	% (g/L)
During Cure (see back page)	<1 (<10)

Shelf Life	Months
Adhesive (A Side)	7
Activator (B Side)	7
Cartridges	7

Typical Exotherm Curve for MA560-1 (30g mass) at Various Ambient Temperatures[5]



TECHNICAL DATA SHEET

PLEXUS MA560-1

SAFETY & HANDLING: ITW Plexus® adhesive (Part A) and activator (Part B) are flammable. Contents include methacrylate esters. Keep containers closed after use. Wear gloves and safety glasses to avoid skin and eye contact. Wash with soap and water after skin contact. In case of eye contact, flush with water for 15 minutes and get medical attention. Harmful if swallowed. Keep out of reach of children. Keep away from heat, sparks, and open flames. For more complete heath and safety information contact ITW Plexus for a Material Safety Data Sheet (MSDS).

NOTE: This material is mass sensitive. A large amount of heat may be generated when large masses of material are mixed at one time. Further, the heat generated by the exotherm resulting from the mixing of large masses of this system can result in the release of entrapped air, steam, and volatile gases. To prevent this, dispense only enough material as needed for the application and for use within the working time of the product and confine gap thickness to no more than its maximum gap fill capability. Questions relative to handling and applications should be directed to ITW Plexus at 800-851-6692.

DISPENSING ADHESIVE AND APPLICATION: ITW Plexus Adhesives may be applied manually or with all stainless steel bulk dispensing equipment. Automated applications may be accomplished with a variety of 1-to-1 meter-mix equipment delivering both components to a static mixer. Avoid contact with copper or copper-containing alloys in all fittings, pumps, etc. Seals and gaskets should be made of Teflon, Teflon-coated PVC foam, ethylene/propylene, or polyethylene. Avoid the use of Viton, BUNA-N, Neoprene, or other elastomers for seals and gaskets. For more information, contact ITW Plexus. To assure maximum bond strength, surfaces must be mated within the specified working time. Use sufficient material to ensure the joint is completely filled when parts are mated and clamped. All adhesive application, part positioning, and fixturing should occur *before* the working time of the mix has expired. After indicated working time, parts must remain undisturbed until the fixture time is reached. Clean up is easiest *before* the adhesive has cured. Citrus terpene or N-methyl pyrrolidone (NMP) containing cleaners, degreasers, and soap and water can be used for best results. If the adhesive is already cured, careful scraping, followed by a wiping with a cleaning agent, may be the most effective method of clean up.

EFFECT OF TEMPERATURE: Application of adhesive at temperatures between 65°F (18°C) and 85°F (30°C) will ensure proper cure. Temperatures below 65°F (18°C) or above 85°F (30°C) will slow down or increase cure rate significantly, respectively. Temperature affects viscosities of Parts A and B of this adhesive. To ensure consistent dispensing in meter-mix equipment, adhesive and activator temperatures should be held reasonably constant throughout the year. Adhesive in cured state behaves differently at elevated and low temperatures. See ITW Plexus for specific values.

STORAGE AND SHELF LIFE: Shelf life is based on continuous storage between 54°F (12°C) and 74°F (23°C). Long-term exposure above 74°F (23°C) will reduce the shelf life. Prolonged exposure above 98°F (37°C) quickly diminishes the reactivity of the product. These products should never be frozen.

VOC'S: As calculated according to Appendix A to Subpart PPPP of EPA Part 63, Plastics Part and Coatings MACT. The amount of volatile material released when 10-15g of mixed adhesive is allowed to cure between foil for 24 hours at room temperature followed by 1 hour at 220°F (104°C). See ITW Plexus for specific values.

PRODUCT USE: Many factors beyond ITW PLEXUS® control and uniquely within user's knowledge and control can affect the use and performance of an ITW PLEXUS® product in a particular application. Given the variety of factors that can affect the use and performance of an ITW PLEXUS® product, the end user is solely responsible for evaluating any ITW PLEXUS® product and determining whether it is fit for a particular purpose and suitable for user's design, production and final application.

EXCLUSION OF WARRANTIES: AS TO THE HEREIN DESCRIBED MATERIALS AND TEST RESULTS, THERE ARE NO WARRANTIES WHICH EXTEND BEYOND THE DESCRIPTION ON THE FACE HEREOF ITW PLEXUS® MAKES NO OTHER WARRANTIES, EXPRESS OR IMPLIED, INCLUDING, BUT NOT LIMITED TO ANY IMPLIED WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE. SINCE THE USE OF THE HEREIN DESCRIBED INVOLVES MANY VARIABLES IN METHODS OF APPLICATION, DESIGN, HANDLING AND/OR USE, THE USER, IN ACCEPTING AND USING THESE MATERIALS, ASSUMES ALL RESPONSIBILITY FOR THE END RESULT. ITW PLEXUS® SHALL NOT OTHERWISE BE LIABLE FOR LOSS OF DAMAGES, WHETHER DIRECT, INDIRECT, SPECIAL, INCIDENTAL OR CONSEQUENTIAL, REGARDLESS OF THE LEGAL THEORY ASSERTED, INCLUDING NEGLIGENCE, WARRANTY OR STRICT LIABILITY.

Notes

1. **ITW Plexus strongly recommends that all substrates be tested with the selected adhesive in the anticipated service conditions to determine suitability.**
2. **Working Time: The time elapsed between the moment Parts A and B of the adhesive system are combined and thoroughly mixed and the time when the adhesive is no longer useable. Times presented were tested at 74°F (23°C).**
3. **Fixture Time: Varies with bond gap and ambient temperature. Present values were measured at 74°F (23°C).**
4. **Resistance to chemical exposure varies greatly based on several parameters including temperature, concentration, bond line thickness, and duration of exposure. The chemical resistance guidelines listed assume long-term exposures at ambient conditions.**
5. **In a typical bond line, exotherm temperatures will be lower than the temperatures shown.**
6. **All adhesives soften with temperature and should be evaluated at expected conditions. Consult with ITW Plexus for values at a specific temperature.**
7. **Exterior applications require the use of coatings or primers that inhibit oxidation of the metals.**

ITW POLYMERS ADHESIVES NORTH AMERICA
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Plexus MA560-1 Rev 04, 09/2013

INTERPLASTIC CORPORATION
Thermoset Resins Division

CORVE8100-50
Vinyl Ester Resin
Technical Data Sheet

CORVE8100-50 is a non-promoted, low viscosity, corrosion resistant vinyl ester resin for use in vacuum infusion and RTM applications. CORVE8100-50 is manufactured from ingredients listed as acceptable in the FDA Code of Federal Regulation Title 21, CFR 177.2420. This resin may be safely used as a component of articles intended for single or repeated use in contact with food as prescribed in the regulation. See “CoREZYN® Vinyl Ester Resins” publication 10/05 A-006b under CORVE8100 for corrosion recommendations and general information.

FEATURES	BENEFITS
• Moderate Laminate Exotherm	• Good cosmetic surface and minimal glass print
• Fast Trim Time	• Shorter cycle times and fast Barcol development
• Good Fiberglass Wet-Out	• Easy roll-out and high laminate physical properties
• Non-Promoted Resin System	• Allows for flexibility in timing of manufacture

LIQUID PROPERTIES	RESULTS
Viscosity, Brookfield Model LV #2 Spindle @ 60 rpm, 77°F (25°C), cps	80-120
100 grams resin @ 77°F (25°C), promoted with 0.10 gram 12% Cobalt and 0.10 gram 2,4-Pentanedione, catalyzed with 1.2% Hi-Point 90 by volume *	
Gel Time, min:sec	70:00-90:00
Gel to Peak Exotherm Time, min:sec	10:00-25:00
Peak Exotherm	340-390°F (171-198°C)
Non-Volatile Content, %	48.0-52.0
Hazardous Air Pollutant (Styrene) Content, %	48.0-52.0
Specific Gravity	1.00-1.04

TYPICAL PROPERTIES

Thickness	1/8 inch (3.2 mm) Casting				1/8 inch (3.2 mm) Laminate			
Construction	Not Applicable				4 Plies 1.5 oz/ft^2, 66% Glass Mat			
Flexural Strength, ASTM D790	19,000	psi	131	MPa	44,900	psi	310	MPa
Flexural Modulus, ASTM D790	4.7 x 10^5	psi	3,241	MPa	19.6 x 10^5	psi	13,500	MPa
Tensile Strength, ASTM D638	11,800	psi	81	MPa	28,400	psi	196	MPa
Tensile Modulus, ASTM D638	4.9 x 10^5	psi	3,379	MPa	26.6 x 10^5	psi	18,350	MPa
Tensile Elongation, ASTM D638	4.5	%	4.5	%	1.5	%	1.5	%
Barcol Hardness, 934-1 gauge, ASTM D2583	36		36		55-60		55-60	
Heat Distortion Temperature, ASTM D648	210	°F	99	°C	--	°F	--	°C

* The gel time and reactivity will vary due to the type and concentration of Free Radical Initiator (catalyst), shop temperature, humidity, and type of fillers used. In order to meet your individual needs consult our technical sales representative for assistance.

INTERPLASTIC CORPORATION
2015 Northeast Broadway Street
Minneapolis, Minnesota 55413-1775
651.481.6860 Fax: 612.331.4235
www.interplastic.com

Revised: 11/06

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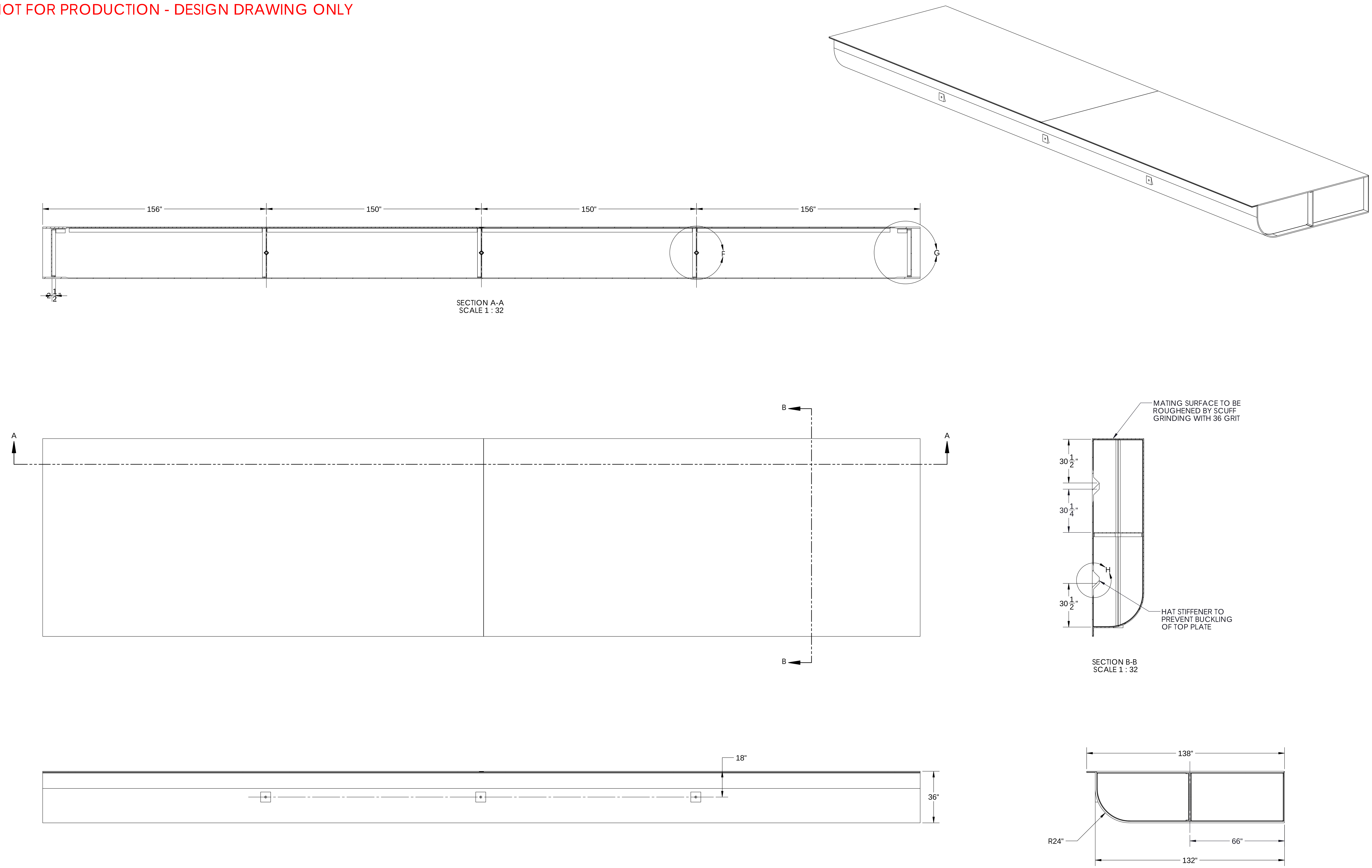


KENWAY CORP.

DATE	DESCRIPTION	REV

SEAL

DIMENSIONS ARE IN INCHES
TOLERANCES: +0, -1/16"
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

DRAWN BY	DATE
JM	4/17/14
CHKD BY	DATE
XX	X/X/XX

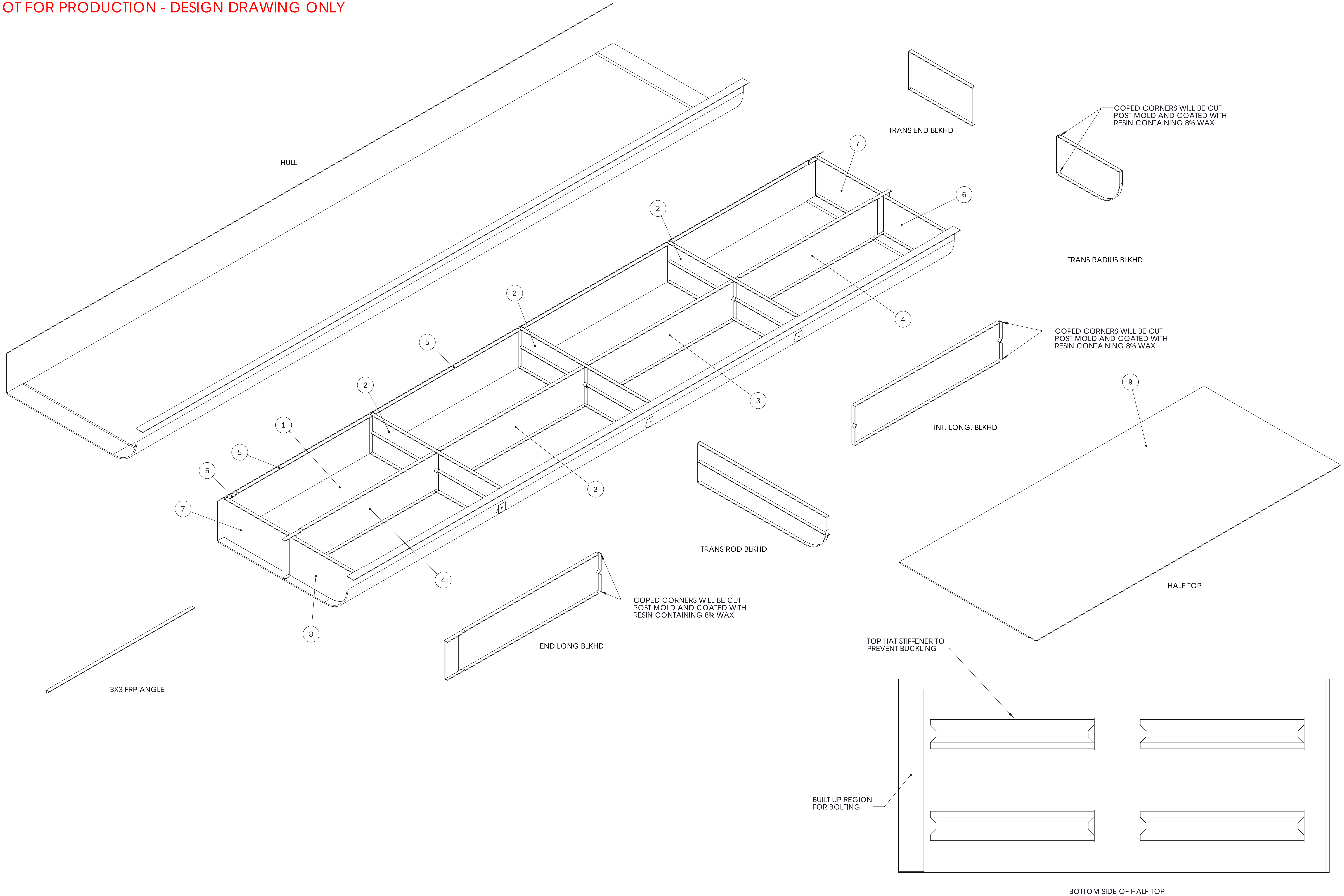
PROJECT: BROOKFIELD FRP PONTOONS

CUSTOMER: MILLER CONST. / VTRANS

SHEET: STANDARD PONTOON GENERAL ARRANGEMENTS

WEIGHT:	12,644 lb
DESCRIPTION:	DESIGN DWG
SCALE	1 : 32
WO NO.	8420
CONTRACT NO.	9185
DWG NO.	8420-1
SHEET	1 OF 5
PONTOON	N/A
PART NO.	N/A

NOT FOR PRODUCTION - DESIGN DRAWING ONLY



KENWAY CORP.

REV	DESCRIPTION	DATE

SEAL

DIMENSIONS ARE IN INCHES
TOLERANCES: +0, -1/16"
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

DRAWN BY	DATE
JM	4/3/14
CHKD BY	DATE
XX	X/X/XX

PROJECT: BROOKFIELD FRP PONTOONS

CUSTOMER: MILLER CONST. / VTRANS

SHEET: STANDARD PONTOON COMPONENTS

WEIGHT: N/A

DESCRIPTION: DESIGN DWG

SCALE 1 : 32

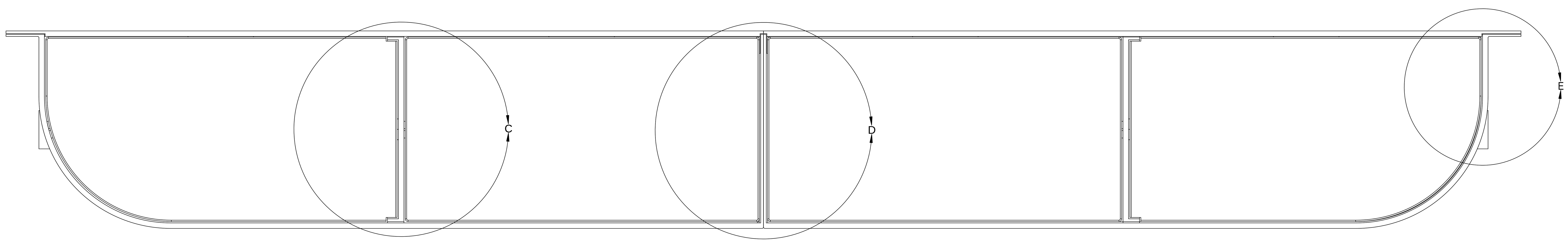
WO NO. 8420

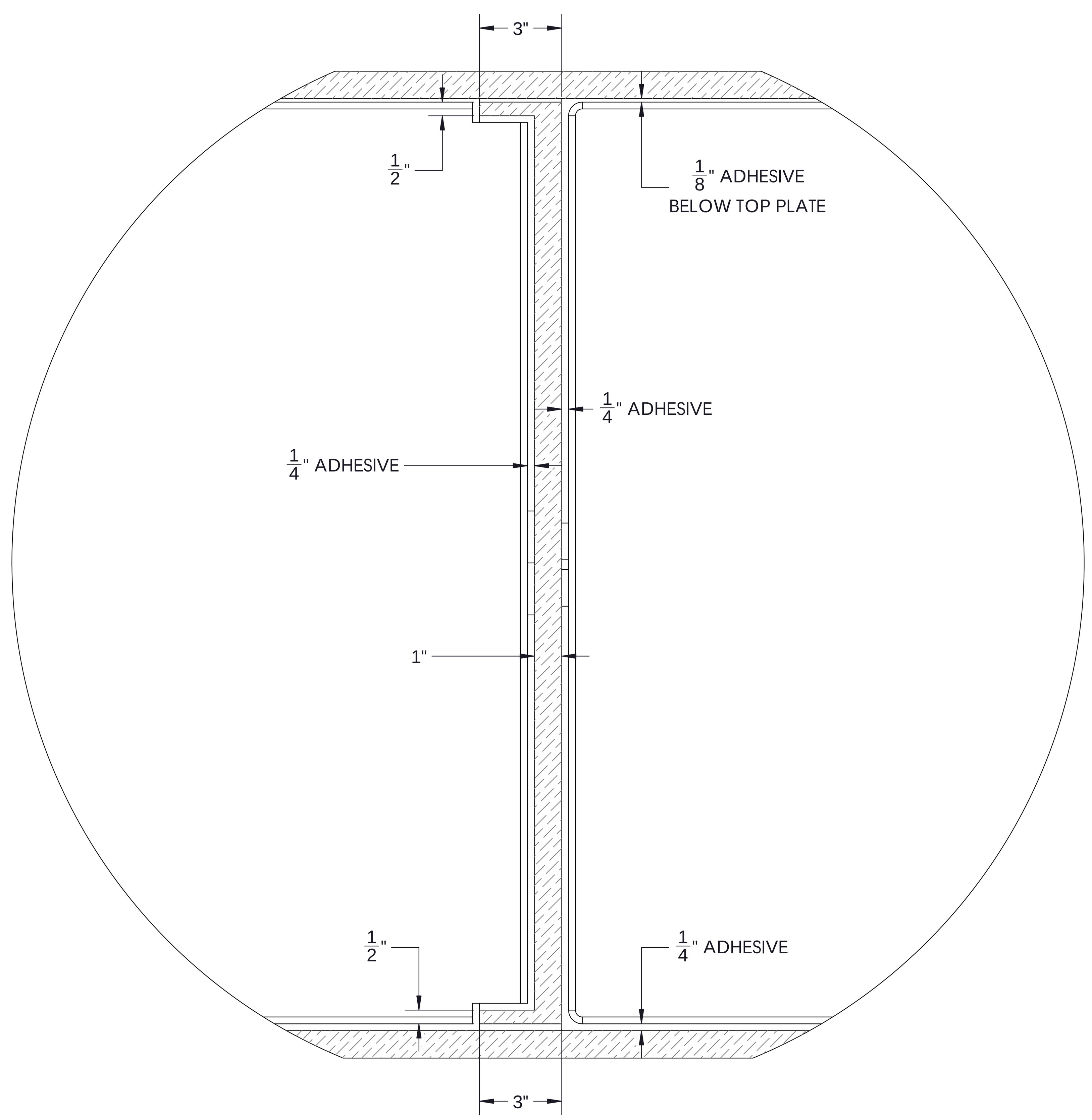
CONTRACT NO. 9185

DWG NO. 8420-1

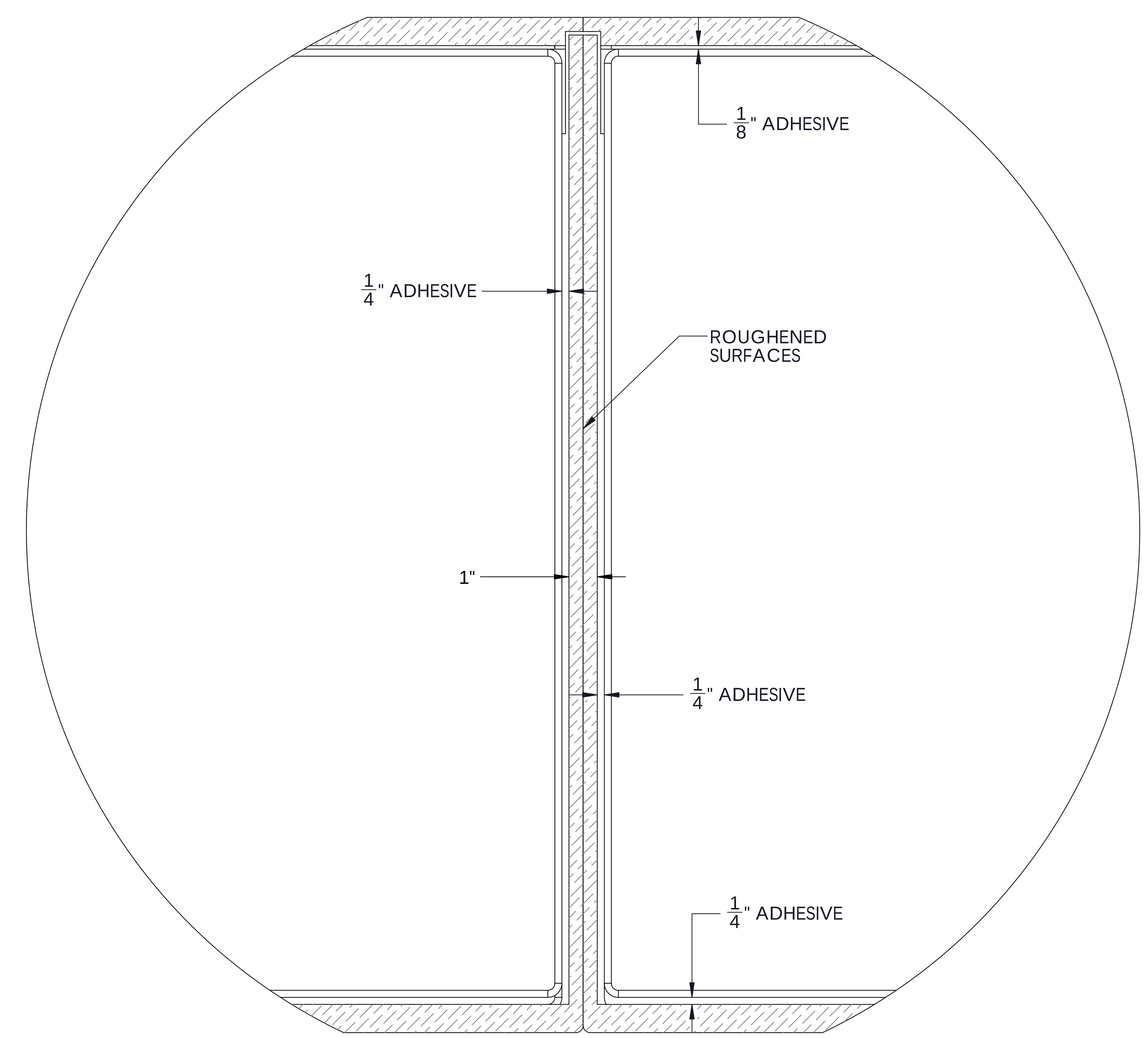
SHEET 2 OF 5

PONTOON	PART NO.
N/A	N/A

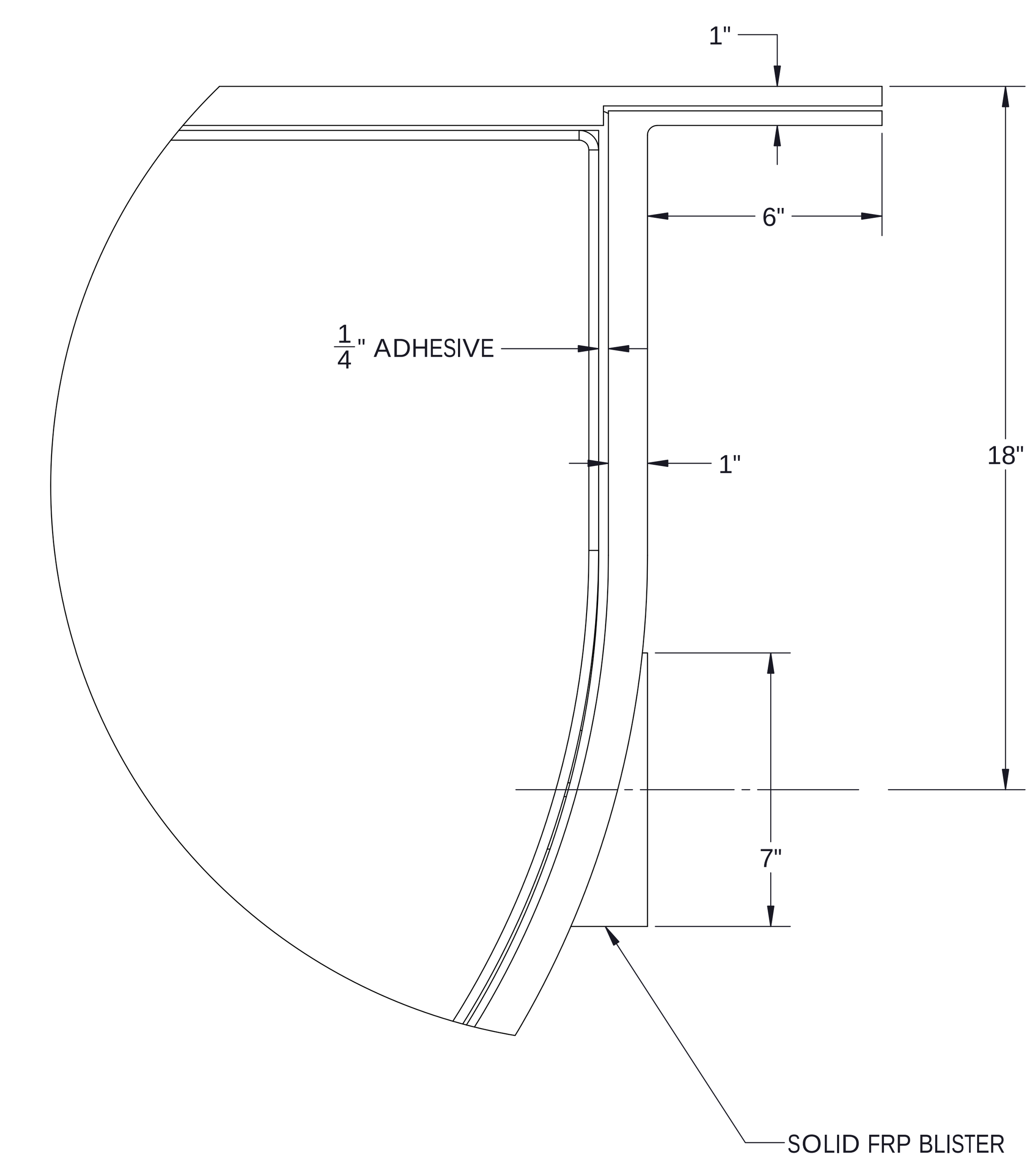




DETAIL C
SCALE 1 : 4



DETAIL D
SCALE 1 : 4



DETAIL E
SCALE 1 : 4

NOT FOR PRODUCTION - DESIGN DRAWING ONLY

KENWAY CORP.

REV	DESCRIPTION	DATE

SEAL

DIMENSIONS ARE IN INCHES
TOLERANCES: +0, -1/16"
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

DRAWN BY	DATE
JM	4/17/14
CHKD BY	DATE
XX	X/X/XX

PROJECT: BROOKFIELD FRP PONTOONS

CUSTOMER: MILLER CONST. / VTRANS

SHEET: STANDARD PONTOON END DETAILS

WEIGHT: N/A

DESCRIPTION: DESIGN DWG

SCALE 1 : 12

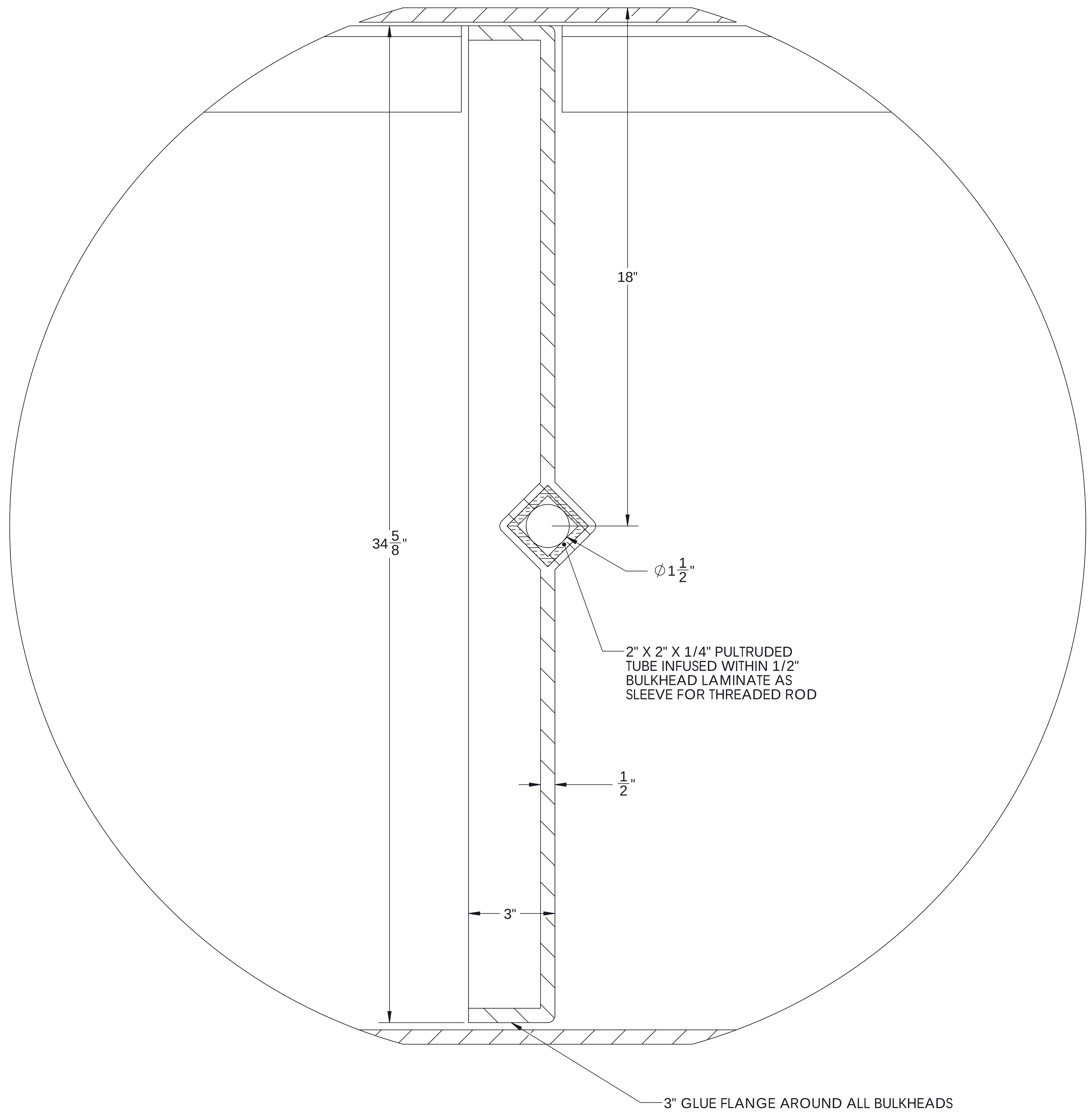
WO NO. 8420

CONTRACT NO. 9185

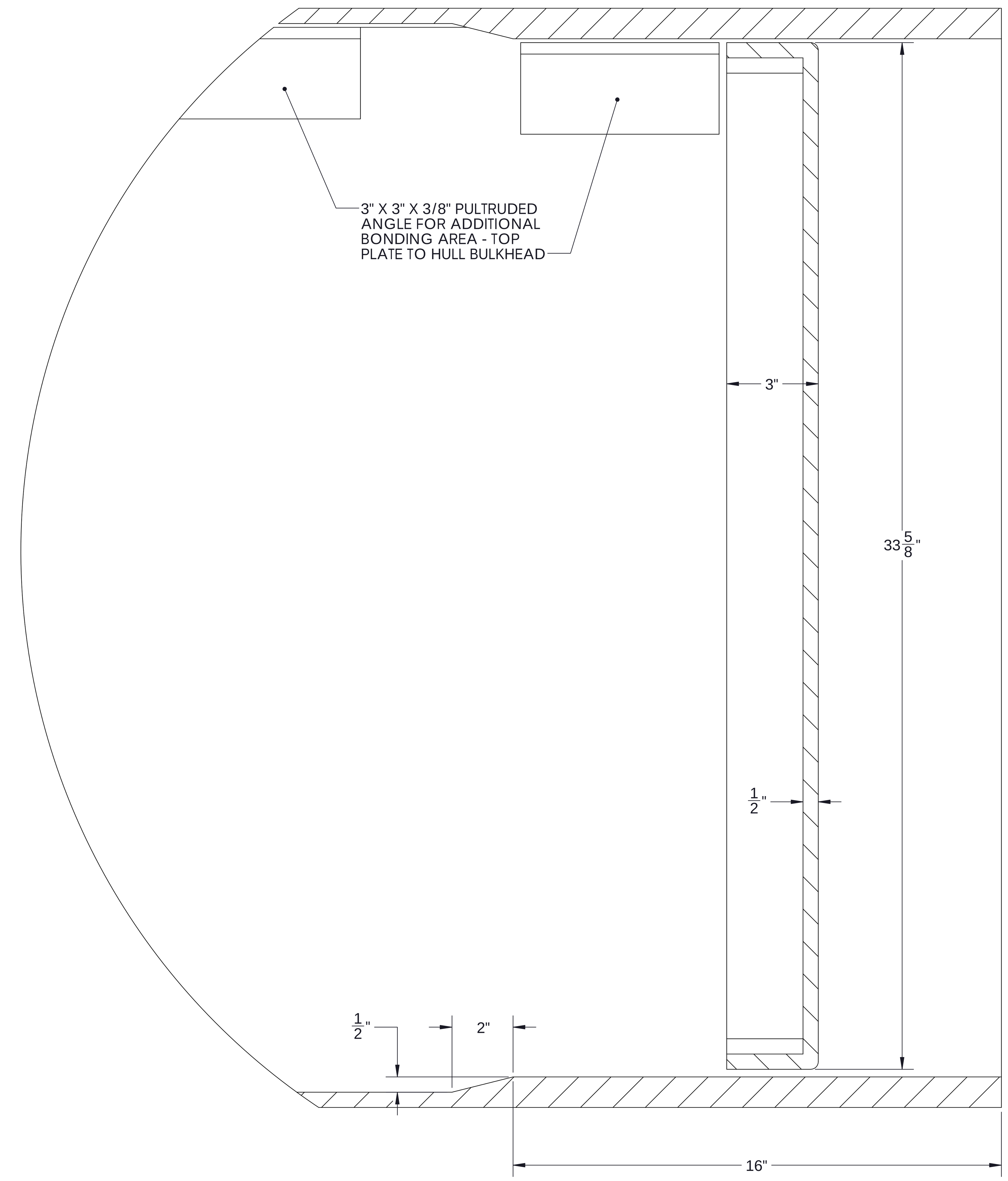
DWG NO. 8420-1

SHEET 3 OF 5

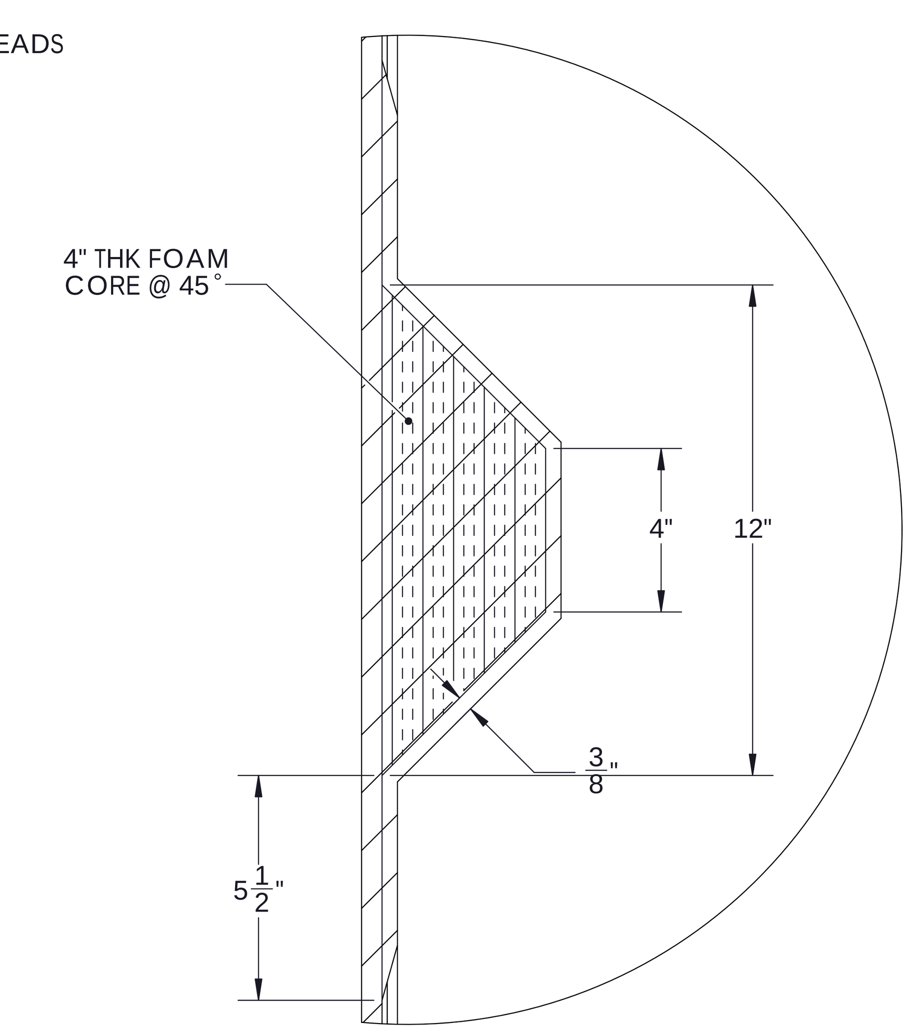
PONTOON	PART NO.
N/A	N/A



DETAIL F
SCALE 1 : 3



DETAIL G
SCALE 1 : 3



DETAIL H
SCALE 1 : 4

NOT FOR PRODUCTION - DESIGN DRAWING ONLY

KENWAY CORP.

DATE	DESCRIPTION	REV

SEAL

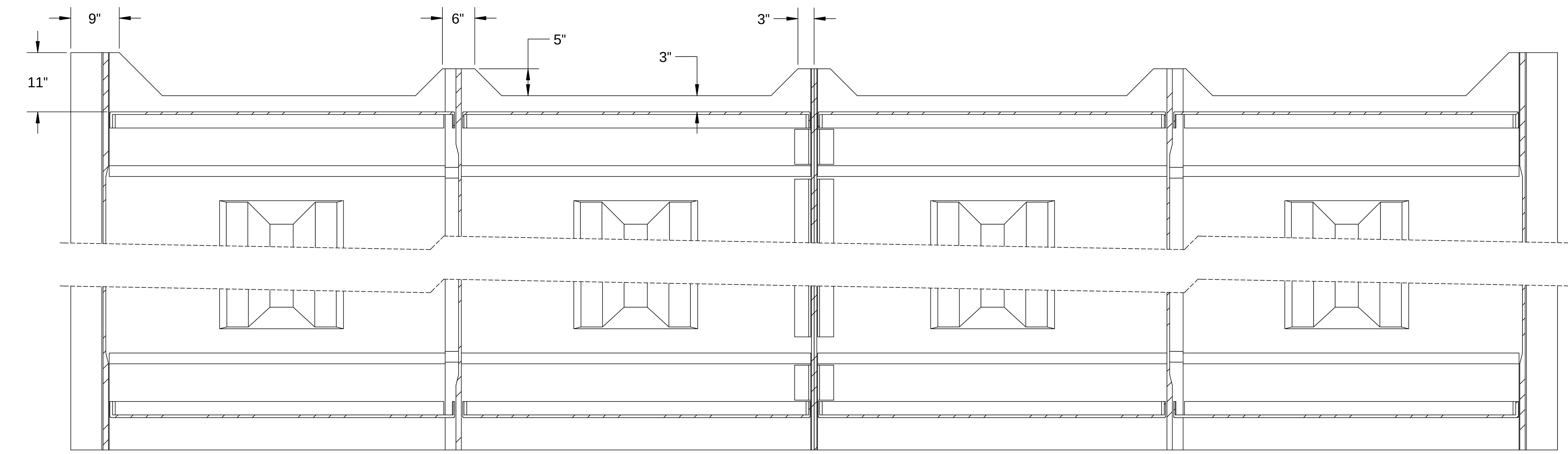
DIMENSIONS ARE IN INCHES
TOLERANCES: +0, -1/16"
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

DRAWN BY JM	DATE 4/17/14
CHKD BY XX	DATE X/X/XX

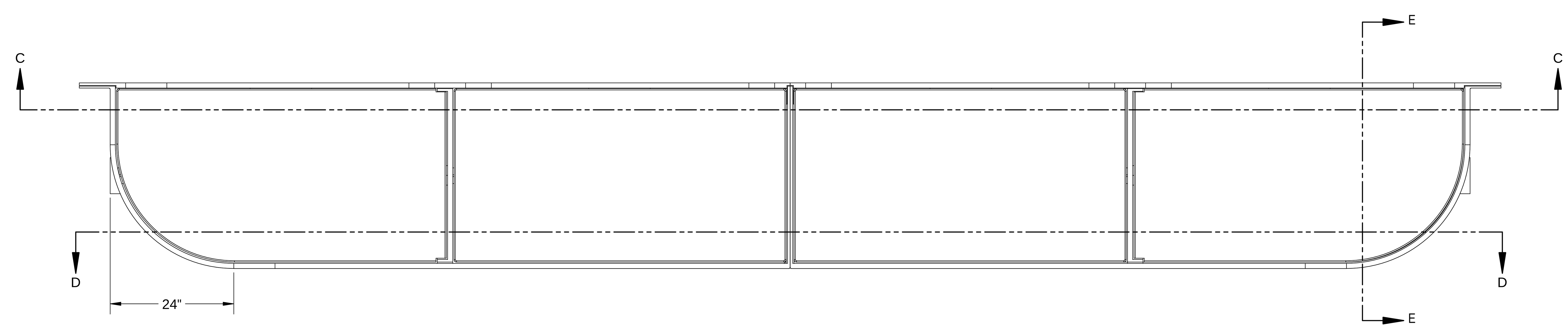
PROJECT: BROOKFIELD FRP PONTOONS
CUSTOMER: MILLER CONST. / VTRANS
SHEET: INTERMEDIATE PONTOON GENERAL ARRANGEMENTS

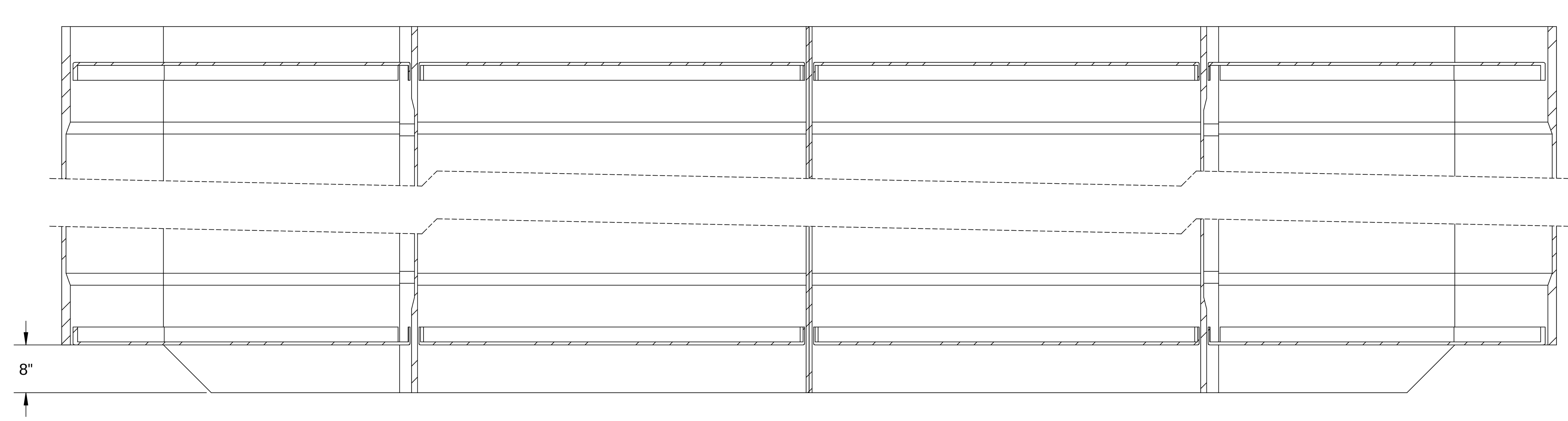
WEIGHT: 12,644 lb
DESCRIPTION: DESIGN DWG
SCALE 1 : 2
WO NO. 8420
CONTRACT NO. 9185
DWG NO. 8420-1
SHEET 4 OF 5

PONTOON	PART NO.
N/A	N/A

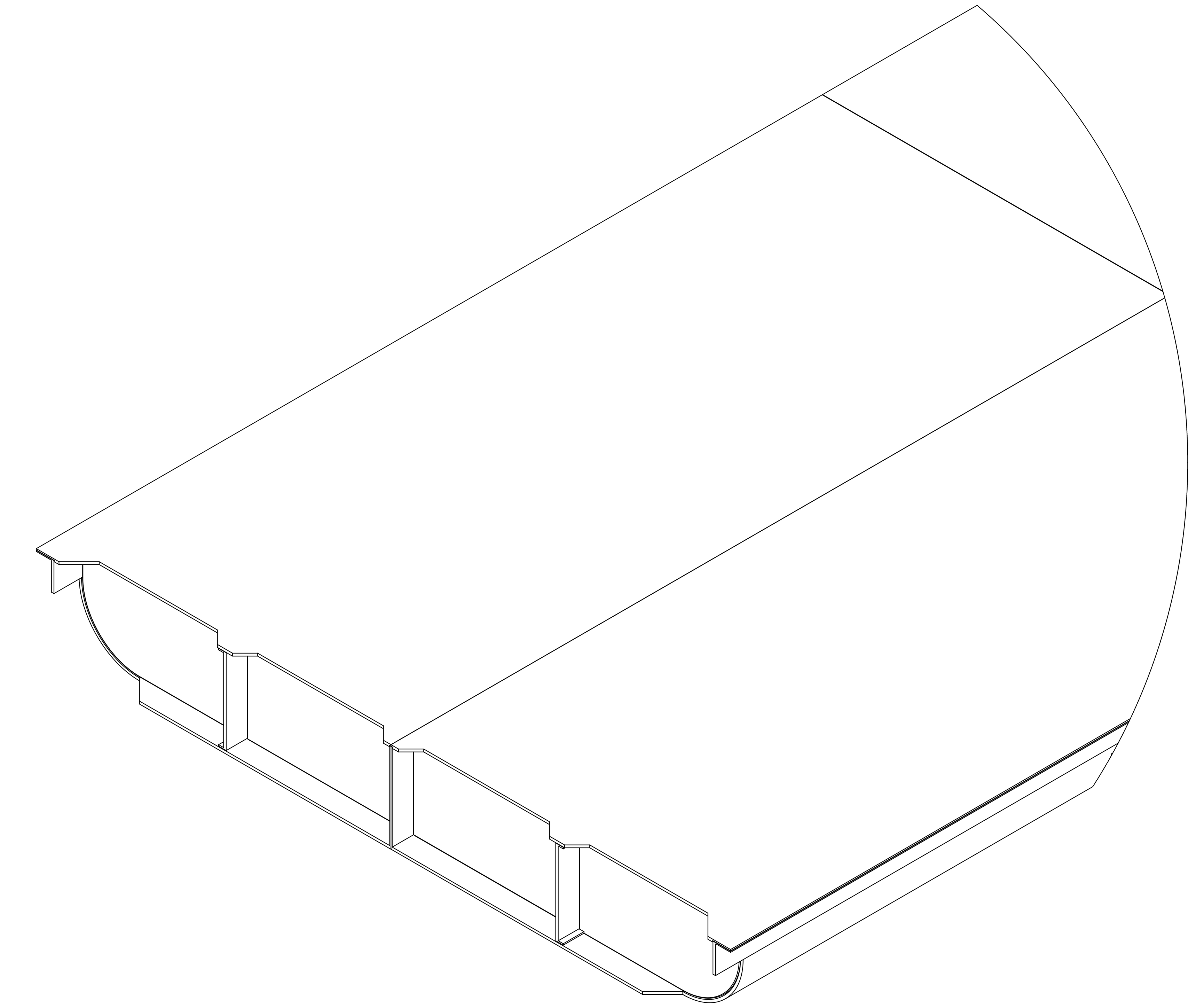


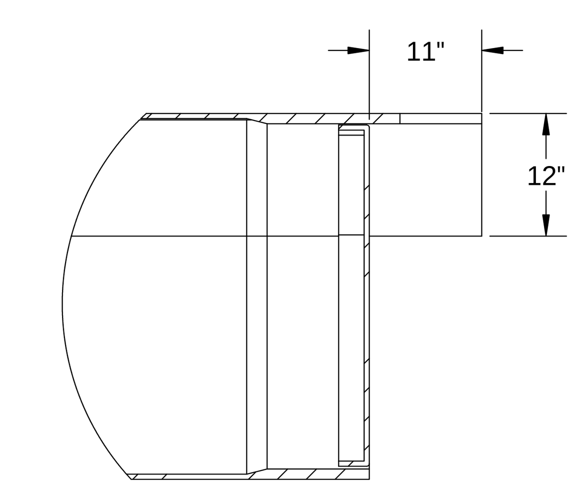
SECTION C-C
SCALE 1 : 16





SECTION D-D
SCALE 1 : 16





SECTION E-E
SCALE 1 : 16

NOT FOR PRODUCTION - DESIGN DRAWING ONLY

KENWAY CORP.

REV	DESCRIPTION	DATE

SEAL

DIMENSIONS ARE IN INCHES
TOLERANCES: +0, -1/16"
FRACTIONAL ± BEND ±
ANGULAR: MACH ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

DRAWN BY	DATE
JM	4/17/14
CHKD BY	DATE
XX	X/X/XX

PROJECT: BROOKFIELD FRP PONTOONS

CUSTOMER: MILLER CONST. / VTRANS

SHEET: END RAFT FALNGE AND WEB DETAILS

WEIGHT: 12,644 lb

DESCRIPTION: DESIGN DWG

SCALE 1 : 16

WO NO. 8420

CONTRACT NO. 9185

DWG NO. 8420-1

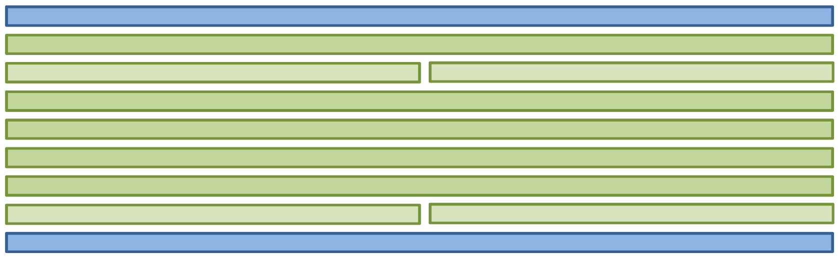
SHEET 5 OF 5

PONTOON	PART NO.
N/A	N/A

Planned Deviations from the Specifications or Conceptual Design

Overlap in 0/90 Fabric Layers

In all strength calclulations, the actual thickness required for the factored strength to meet the factored loads is less than 1/8". The minimum laminate thickness throughout is 1/2". Given that the average thickness of each ply is 0.058", the strength could be achieved with only 2.2 continuous plies (round up to 3). Therefore, if minimum seam spacing of 2' is maintained and no more than 2 seams at a given location, then for any butt seam (discounting 2 plies with seams) there are 4 additional plies above and/or below the seam tying the laminate together. Kenway would like to request that all 0/90 fabric can be butted and not overlapped. Since the ±45 outer plies are single ply lamina (no adjacent plies of similar material), these fabric



Match-casting Hull Sections

Match-casting adjacent hull sections would be nearly impossible while ensuring vacuum integrity for the resin infusion process. Kenway proposes to rely on accurate construction and inspectoin of the hull mold to ensure that the adjoining vertical sections are straight and perpendicular to the baseline. The pontoons will be joined at Kenway to ensure proper fit and that the resulting geometry satisifies the specification

Cutting of Hull Sections

Standard pontoon ends will be formed in the mold net-shape. No cutting other than normal trimming of flashing is planned. The ends of the end rafts will also be net-shape molded. Some minor cutting and trimming is expected to finalize the shape. However, any laminate that is cut will be final coated with the same resin to seal end grain and exposed fibers.

Stainless vs. FRP Shim Plates

Kenway proposes the use of FRP shim plates in lieu of stainless steel shim plates between the interior web shelf support plates. Stainless is required to have a minimum yield strength of 30 ksi. The FRP will have a compressive strength of at least 35 ksi. The FRP shim plates can be more easily formed to the precise thickness required and will not cause any corrosion.

Submarine Camel Laminate Tests

Prepared for:

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AEWC Report Number
12-23.1039

December 22, 2011

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An ISO 17025 accredited testing laboratory
Accredited by International Accreditation Service

ACCREDITED

Submarine Camel Laminate Tests

Kenway Corporation (herein Client) requested the following series of tests to be performed on a 0/90 GRFP laminate which represents a material to be used in the construction of a submarine camel:

1. ASTM D3039 “Standard Test Method for Tensile Properties of Polymer Matrix Composite Materials”; Tested in 0° and 90° directions. Specimens conditioned to standard laboratory environment (21°C, 50% RH).

2. ASTM D3039 “Standard Test Method for Tensile Properties of Polymer Matrix Composite Materials”; Tested in 0° and 90° directions. Specimens will be conditioned following ASTM D618, Procedure E (immersion in water at 50°C for 48 hours).

3. ASTM D6641 “Standard Test Method for Compressive Properties of Polymer Matrix Composite Materials Using a Combined Loading Compression (CLC) Test Fixture”; Tested in 0° and 90° directions. Specimens conditioned to standard laboratory environment (21°C, 50% RH).

4. ASTM D6641 “Standard Test Method for Compressive Properties of Polymer Matrix Composite Materials Using a Combined Loading Compression (CLC) Test Fixture”; Tested in 0° and 90° directions. Specimens will be conditioned following ASTM D618, Procedure E (immersion in water at 50°C for 48 hours).

5. ASTM D2584 “Standard Test Method for Ignition Loss of Cured Reinforced Resins”.

Description of test specimens

The Client delivered the sample panel on November 17, 2011. The panel was fabricated by the Client using three plies of V2 Composites VT102 0/90 fabric and infused with CCP Epovia RF1001 resin. The panel was identified as Part # 7682-9. The approximate dimensions of the panel were 24 in. x 48 in. x 0.28 in. thick.

The panel was post cured at AEWC in an ESPEC environmental chamber on November 21, 2011. The ESPEC was programmed to execute the following post cure cycle:

1. From ambient, increase temperature 1°F(1.8°C)/min up to 180°F(82.2°C)
2. Hold at 180°F(82.2°C) for 2 hrs

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3. Increase temperature 1°F(1.8°C)//min up to 225°F(107.2°C)
4. Hold at 225°F(107.2°C) for 2 hrs
5. Cool to ambient at 2°F(3.2°C)/min

Following the post cure process, the panel was cut in half using a water-cooled abrasive saw. The tension and compression specimens were cut from the panel halves using a water jet machine. All of the 0° specimens were cut from one of the panel halves, and the 90° specimens were cut from the other half. The tension specimens were rectangular; 10 in. long and 1 in. wide. The compression specimens were rectangular, 5.5 in. long and 0.5 in. wide.

The gage areas of all the test specimens were painted with a random black speckle pattern on a white background. This pattern is used by the Aramis digital image correlation system to measure full field strain on one face of the specimens during testing.

One half of the specimens from each type of test (tension and compression) and orientation (0° and 90°) were sealed in containers filled with deionized water. The containers were placed in the ESPEC chamber on December 2, 2011 and held at 50°C for 48 hours. This conditioning conforms to ASTM D618 Procedure E. Following this treatment, these specimens were stored in the same water at ambient temperature until just before testing.

Testing of tensile properties: ASTM D3039

Tensile tests were performed December 5, 2011 on an Instron servo-hydraulic test machine with a load capacity of 22 kips. A 22 kip capacity Instron load cell was used to measure the applied loads. An Aramis digital image correlation system was used to measure strain during the tests. The tests were performed using a constant crosshead speed of 0.05 in./min.

Table 1 contains a summary of the results from the tensile testing. The specimens that were conditioned to the laboratory ambient environment are identified by the “dry” heading at the top of the columns. The specimens that were conditioned in water are identified as the “wet” specimens. Each wet specimen was removed from the water just prior to testing. The specimen surfaces were wiped dry with a cotton cloth before clamping the specimen in the test machine.

The modulus of elasticity (MOE) values reported in Table 1 were computed from the strain data collected with the Aramis system. The MOE was calculated as the slope of the tensile stress vs. the longitudinal strain, over a strain range of 0.001 to 0.003. The Poisson’s ratio was calculated by taking the MOE and dividing it by slope of stress vs. the transverse strain over the same strain range as the MOE.

Table 1: ASTM D3039 Tension Test Results

Tension	0° Dry	0° Wet	90° Dry	90° Wet
UTS, Average (ksi)	64.3	61.9	59.6	57.1
Std. Dev. (ksi)	2.46	3.38	5.10	3.42
COV	3.8%	5.5%	8.6%	6.0%
Number of tests in results	6	8	6	6
MOE, Average (Msi)	3.81	3.75	3.96	3.94
Std. Dev. (Msi)	0.25	0.33	0.10	0.14
COV	6.5%	8.7%	2.5%	3.6%
Number of tests in results	5	8	8	8
Poisson’s Ratio, Average	0.092	0.102	0.183	0.190
Std. Dev.	0.008	0.020	0.012	0.012
COV	8.7%	19.2%	6.5%	6.4%
Number of tests in results	5	8	8	8
Thickness, Average (in)	0.280	0.284	0.275	0.279
Std. Dev. (in)	0.004	0.006	0.008	0.006
COV	1.3%	2.2%	3.0%	2.1%
Number of tests in results	8	8	8	8

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Testing of compressive properties: ASTM D6641

Compression tests were performed December 6-7, 2011 on an Instron servo-hydraulic test machine with a load capacity of 22 kips. A 22 kip capacity Instron load cell was used to measure the applied loads. An Aramis digital image correlation system was used to measure strain during the tests. The tests were performed using a constant crosshead speed of 0.05 in./min.

Table 2 contains a summary of the results from the compression testing. The specimens are identified as dry or wet, as described above for the tension testing. The wet specimen surfaces were wiped dry with a cotton cloth before clamping the specimen into the combined loading compression (CLC) test fixture.

The modulus of elasticity (MOE) values reported in Table 2 were computed from the strain data collected with the Aramis system. The MOE was calculated as the slope of the compressive stress vs. the longitudinal strain, over a strain range of 0.001 to 0.003. The Poisson's ratio was calculated by taking the MOE and dividing it by slope of stress vs. the transverse strain over the same strain range as the MOE.

Table 2: ASTM D6641 Compression Test Results

Compression	0° Dry	0° Wet	90° Dry	90° Wet
UCS, Average (ksi)	70.7	71.6	69.7	69.2
Std. Dev. (ksi)	4.18	1.96	6.40	9.43
COV	5.9%	2.7%	9.2%	13.6%
Number of tests in results	9	6	6	6
MOE, Average (Msi)	3.91	4.30	4.10	4.01
Std. Dev. (Msi)	0.35	0.25	0.29	0.13
COV	8.9%	5.7%	7.1%	3.2%
Number of tests in results	9	6	6	6
Poisson's Ratio, Average	0.199	0.198	0.284	0.298
Std. Dev.	0.068	0.036	0.026	0.058
COV	34.2%	18.4%	9.2%	19.4%
Number of tests in results	8	6	6	6
Thickness, Average (in)	0.283	0.286	0.274	0.279
Std. Dev. (in)	0.006	0.005	0.008	0.008
COV	2.2%	1.8%	2.8%	2.8%
Number of tests in results	9	9	9	9

Ignition loss testing: ASTM D2584

Specimens for the ignition loss testing were cut from untested "dry" tension and compression specimens. (These were extra specimens that were prepared if needed but not tested). Following ASTM D2584, three specimens weighing 9 – 10 grams each were placed in a muffle furnace at 565°C until the resin was completely consumed. The residual material consisting of the glass reinforcement was weighed to determine the weight fraction of glass in the laminate. The ignition loss tests were performed December 16, 2011.

Table 3: ASTM D2584 Ignition loss results

Specimen	Weight Fraction (%)
1	74.95
2	73.78
3	73.52
Average	74.08

Test equipment identification

Table 4 contains the AEWC identification numbers for the equipment used to perform the tests reported on in this document.

Table 4: Equipment list

Equipment	AEWC ID	ASTM D3039	ASTM D6641	ASTM D2584
ESPEC chamber	129	X	X	X
Digital caliper	685	X	X	
Digital micrometer	450	X	X	
Instron 22 kip test machine	1084	X	X	
Instron 22 kip load cell	1085	X	X	
Aramis DIC system	395	X	X	
CLC test fixture	293		X	
Lab scale	657			X
Muffle furnace	180			X